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Local impact of renewables on employment: Assessment methodology and case study

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ABSTRACT

This paper presents an integrated method that assesses the socio-economic impact of establishing renewable energy on a regional scale, in particular on the creation of jobs. The method proposed is based on the collection, critical analysis and presentation of the results obtained using primary information sources considering the jobs created as the most direct measure of the socio-economic potential of renewable energy sources. Its design includes contributions extracted from a prior analysis of the existing assessment methods, to lessen the uncertainty of the job ratios often used in these types of analysis. The integrated method implemented has been applied to the autonomous community of Aragon (Spain) as a pilot case, through which the method has been tested and the indicators selected to analyse the socio-economic impact of renewable energy sources on the jobs created, the quality of the jobs and other factors related to the socio-economic development of a territory: technological development, per capita income, territorial development and human capital.

Contents

1. Introduction

While the contribution of renewable energy to the mitigation of climate change and the reliability of the energy supply are generally accepted, the socio-economic aspects linked to the use of renewable energy sources have not been widely studied.

In most cases, the studies on the socio-economic impact of renewable energy sources usually consider some of the specific aspects and provide analyses that are difficult to extrapolate. Those based on "input–output" models, for example, can pose quite a complex interpretation and are limited to use for global and political decisions, as is evident in the results of the MITRE project

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[1] "Meeting the targets and putting RE to work" and as highlighted by, for example, Madlener and Koller [2] in their study, going deeper into some of the aspects analysed by the European Commission in the Final Report of the BIOSEM model [3]. The method used is sometimes only useful for decision-making in very specific areas (see, among others [4–6]), which makes its extrapolation to other economic areas impossible in most cases. The conceptual and methodological framework that establishes the guidelines for drawing up more complete socio-economic analyses, such as for example that offered by Del Río and Burguillo [7], offers the possibility of achieving a global analysis that, nevertheless, can lead to excessive data dispersion and little clarity in the method. For this reason our approach is to opt for a socio-economic analysis of the impact of renewable energy with the employment factor as its starting point, as we consider it to be key for the development of a region and because it offers multiple connections and repercussions in all areas: social, environmental, economic, technological and territorial development.

When concentrating on the specific analysis of the impact on employment posed by the establishment of renewable energy in a territory, the studies are more numerous. An idea that comes up repeatedly and is commonly accepted is that the exploitation of renewable energy for electricity production generates more jobs than plants supplied with conventional energy; for every MW installed it is estimated that renewable energy sources generate between 1.7 and 14.7 times more jobs that natural gas generation plants [8], and up to 4 times more jobs than those supplied with coal [9]. If the impact is calculated per monetary unit invested, the effect of renewable energy sources on the creation of employment is around 1.4 times greater per million dollars invested than in a coal-fired thermal power station over the same period of time [9]. Nevertheless we must highlight that there is a high level of dispersion in the ratios and the order of magnitude, principally due to the various procedures and sources used, as can be appreciated in the compilation by Moreno and López [10]. This dispersion implies a considerable limitation for the use of the ratios offered when estimating or predicting the effect of the use of different renewable energy sources on employment and suggests the need to establish a more complete integrated method that offers clear ratios, based on a higher number of factors and analysed globally.

This paper presents the results of a study developed by a multidisciplinary team specifically focused on drawing up and implementing an innovative and extrapolatable method for analysing the socio-economic impact the exploitation of renewable energy has on a territory. The integrated method implemented has been applied to the autonomous community of Aragon (Spain) as a pilot case and is based on the use of the employment factor, although not in an isolated manner, but rather as the nucleus of an "inside-to-out" analysis, from the specific to the global, that takes into account its effects and repercussions on different socio-economic aspects such as the regional gross domestic product (GDP), the territorial development, the business and industrial structure, the technological development and the installations, the training needs, and the professional profiles and the labour market, etc. offering, in addition, a brief comparison with the ratios of job creation obtained with indices compiled in the bibliography.

2. Analysis of the existing methods

In general terms, to assess the effect of the exploitation of renewable energy sources on employment, the methods used can be classified in two categories: (a) those based on "input–output" (I–O) economic models that examine the economic relationships at domestic level [11–13] and (b) those that use analytical methods [9,14,15].

The creation of an I/O model requires a lot of information so its application in regional spheres is very limited; nevertheless they provide the indirect employment (e.g. the jobs that are created in the metal industry to supply wind turbine manufacturers) and those induced by the multiplier effect of the sector. The analytical models, in general, only calculate the impact on direct employment.

The results obtained through both procedures allow us to estimate coefficients or ratios that quantify the jobs created per unit of installed power or electricity generated using the energy sources considered. There are numerous references in which some of these ratios are compiled [10,14,16]. Nevertheless, in general terms, there is a certain dispersion in the values displayed and significant variability in the ratios used, inherent in the procedure followed to obtain them. As previously mentioned, the I–O indices include the multiplier effect on other economic activity and therefore on the generation of indirect employment. Actually, the ratios deduced in these studies are higher than those obtained by analytical methods. A clear example is found in the study carried out by the Electric Power Research Centre (EPRI) and the California Energy Commission (CEC) [17], which demonstrated that the application of the ratios arising from an I–O model specifically developed for the State of California (USA) anticipates double the number of jobs in the construction stage and triple the number in the operation and maintenance stage than another analytical model developed by the EPRI.

Comparatively, when being interpreted, analytical models are more transparent than I–O models, which means their sensitivity to different factors can be interpreted and even evaluated. Nevertheless the extrapolation of the ratios obtained is not exempt from deviations, which gives rise to the need to develop an integrated method that is transparent in its application like that presented in this study.

As with all empirically adjusted models, to study the impact of renewable energy, the applicability range of the results obtained is defined by the conditions in which the data was gathered. In our opinion, it is necessary to clearly identify certain variables such as the source of the data, the scope of the research, the type of data gathered, the development level of the technology considered, the quality of the jobs, the population density, the structuring of the territory, etc. and specify their influence on the main ratios used.

The data source is important as it predefines the percent error of the results obtained. In the studies consulted as an analysis prior to developing this method, it was observed that the information comes mostly from energy agencies, companies, associations of the different industries, secondary sources, market analyses, etc. in which the accuracy and interpretation of the data are directly related to the objective of the agents involved. Thus, the industrial associations have up-to-date information on the employment the sector generates, while this data is secondary compared to other types of information for energy agencies.

In general terms a significant diversity has been detected with regard to the scope of the research and analysis carried out in each of the studies when calculating the direct and/or indirect employment generated. Thus, there are studies that count the temporary jobs generated in the construction stage of an installation and the stable jobs as result of its operation [7,17] while other studies integrate not only the stages of installation and commissioning but rather all the stages of the supply chain [9] in this ratio.

It has been verified that the percentage dedicated to labour in the stages of the supply chain is very different depending on the technology selected and the size of the installations. The case analysed in the study by Singh and Fehrs [9] to assess employment in photovoltaic energy in an isolated installation of 1 kW would produce different results if it were to analyse the construction of a solar farm connected to the grid.

One variable to be taken into account is the high degree of development in the sector and above all the maturity of the technology considered from the point of view of the industry fabric: the economy of scale and technological development actually influence the human resources needs, sometimes increasing the demand for professionals within the scope of R+D and sometimes reducing jobs in the manufacturing industry, which is gradually applying processes with a greater degree of automation. Some of the studies analysed assume that the employment ratios can be reduced as a result of the economy of scale and the growing experience of the renewable energy industry (the study by Heavner and Churchill [8] assumes an annual decrease of 10% in the construction ratio and 5% in the operation and maintenance ratio, while the reduction in other studies does not follow a fixed reference, for example the study by Kammen et al. [16]).

Regarding terminology and ratios used, in most of the studies when analysing the manufacture and construction stage, the ratio "person-year per MW installed" is most frequently used as the labour force in this stage is temporary, while in the operation and maintenance and fuel processing stages the ratio "number of jobs per MW installed", i.e., the number of people that would need to be employed continuously to operate the plant is usually used. To estimate the total employment associated with each technology, it is necessary to give these employment figures a common base. In this respect, the authors agree with Kammen et al. [16] on the need to consign the number of jobs throughout the whole life of an installation through the ratio "number of jobs per MW". This is converted directly using data from the "people-year per MW" simply by distributing the data over the years of life of the installation. A ratio of 32.3 people-year in the manufacture and installation stages of an isolated photovoltaic installation of 1 MW thus becomes 1.3 jobs, derived from the manufacture and installation stage, distributed as an average throughout the lifetime of the modules. In reality, these jobs are concentrated in the first years of the installation's service life, and only if this type of plant were built without continuity solutions would this ratio indicate the permanent employment inherent in the first stages of the exploitation. From here the need arises to separate the ratios of jobs generated in the manufacture and installation to later add the number of jobs per MW installed corresponding to the operation and maintenance stages in a second stage. Thus obtaining the average number of jobs generated is more realistic and can be used as jobs throughout the service life of the installations. The ratio related to the seasonal employment created finally by the updating, replacement and/or dismantling of the plants and/or installations will be added to this.

In general terms, the studies analysed provide two separate ratios, one for the construction and manufacture and another for the operation and maintenance stage, making it difficult to interpret in some cases exactly which stages are considered in each ratio. For example in the study carried out in Germany by Lehr et al. [12] the installers are added to the ratio corresponding to the jobs generated in operation and maintenance, to be able to differentiate between jobs that are probably local and jobs that may be created in distant manufacturing plants. Other studies such as those by EPRI and CEC in California mentioned previously [17] add the jobs in the installation stage to the first of the ratios to make the distinction between temporary and permanent employment.

However, the employment ratios provide a measurement of the technology's potential to generate jobs without the ratios being able to be extrapolated to other territorial and economic situations. For example, in the study by Singh and Fehrs [9] the employment creation ratio in wind farms was 4.8 people-year/MW installed, where 67% of the work occurred in component manufacture, 11% in installation, 20% in service and 2% in transport.[1] The installation of a 30 MW wind farm will generate an employment of 144 people-year approximately that, distributed over 30 years, results in 4.8 stable jobs throughout the whole life of the installation (as explained previously, this would be 0.16 jobs/MW). If the local wind power industry has a structure that considers each and every link of the business chain, the jobs will be local but if the technology is acquired far from the location 67% of the employment will be renounced, with only an average of 1.6 jobs per year in the closest environment. This indicator may even turn out to be even lower due to the temporary nature of some of the stages.

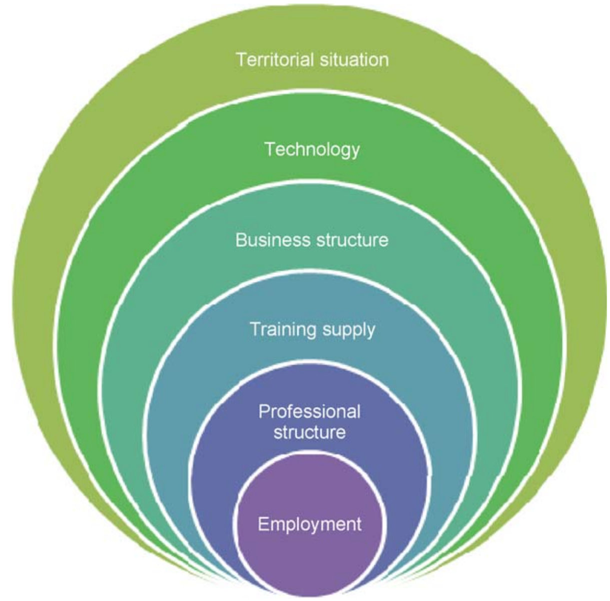

Fig. 1. Outside-to-in view of the impact of the variables on employment.

Although it is undeniable that all the technologies for exploiting renewable energy currently provide interesting opportunities for the creation of employment, it is important to know the structure and functioning of the sub-sector in every study to be able to calculate the related employment ratios correctly.

3. Methodology and approach

The aim of the integrated method presented in this paper is to propose a transparent procedure capable of accurately counting, assessing and interpreting the data on employment linked to the industry of renewable energy sources in a regional environment.

To do this we opted to define a ratio framed by two different sub-ratios: the numeric ratio of jobs generated per MW installed and the ratio of quality expressed in the form of a Quality Factor (QF).

The method was considered as an outside-to-in analysis, in which employment is the core and each level has repercussions on those that surround it, considering that the different variables analysed in the outer levels and the indicators transfer the final influence of these on the ratios. Using the outside-to-in and specific-to-global analysis, an integral interpretation of the results can be achieved from inside to out, from the global to the specific (Fig. 1).

3.1. Classification of the activities

The starting point for the organisation of the information was to classify the activity according to the life cycle of the exploitations of renewable energy sources.

[1] Transport is usually considered to be integrated in the last three stages of the aforementioned life cycle.

Table 1
Stages considered in the study and influence on the volume and quality of employment.

Phase	Volume of generation	Location (from higher to lower probability)	Temporary nature	Level of specialisation
(F1) Technological development	Medium	From foreign to local	Stable	Very high
(F2) Installation/uninstallation	High	From local to foreign	Temporary	High
(F3) Operation and maintenance	Low	Local	Stable	Medium

Although every technology has specific characteristics, they all have a common life cycle that includes 5 stages:

(1) Research and design;
(2) Development and manufacture;
(3) Construction and installation;
(4) Operation and maintenance or service;
(5) Updating and/or dismantling.

To include the influence of the business structure in the development of the sector and specifically in the delocalisation of employment, in its temporary or stable nature and in the need for a professional specialisation in the analysis, we considered reducing the 5 above stages to 3.

Firstly it was deemed more suitable to deal with the first two in a similar way due to the high probability that the employment is generated in an area other than where the installation will finally be located. Thus the new initial stage of "Technological development" includes the jobs created for the R+D and manufacture of the equipment.

Although stages 3 and 5 are distanced in time, they are not in terms of the type of activity and characteristics of the employment involved, so they make up a single stage of "Installation/uninstallation".

The activities involved in maintaining the operativity of an installation are the third and last phase proposed in this method. These activities include from the operation and maintenance of a wind farm to the collection, supply and logistics work of biomass and, in general, the jobs are created and remain within the environment of the installations.

Table 1 shows the basic characteristics of the jobs created in each phase of activity considered.

In subsequent analyses of employment in the territory, this classification may be helpful to demonstrate the need to introduce a strategy that improves the creation of employment in one of these three stages such as through boosting innovation (which increases the impact on the local economy of the jobs in stage 1) or professional training (which reduces the need for foreign installers).

3.2. Definition and selection of the indicators

For the calculation and definition of the ratios, the different indicators shown in Fig. 2 were defined, selected and analysed. These indicators were selected to identify and calculate the two sub-ratios independently, not only in terms of the quantity of jobs created but also of their quality. For this purpose a selection of variables were added that directly influence the selected indicators. The outside-to-in analysis was done taking into account the relationship between the indicators and variables, as shown in Fig. 2.

3.3. Selection of the variables

Once the stages were defined, the related variables were chosen, analysing the interconnection between each variable and

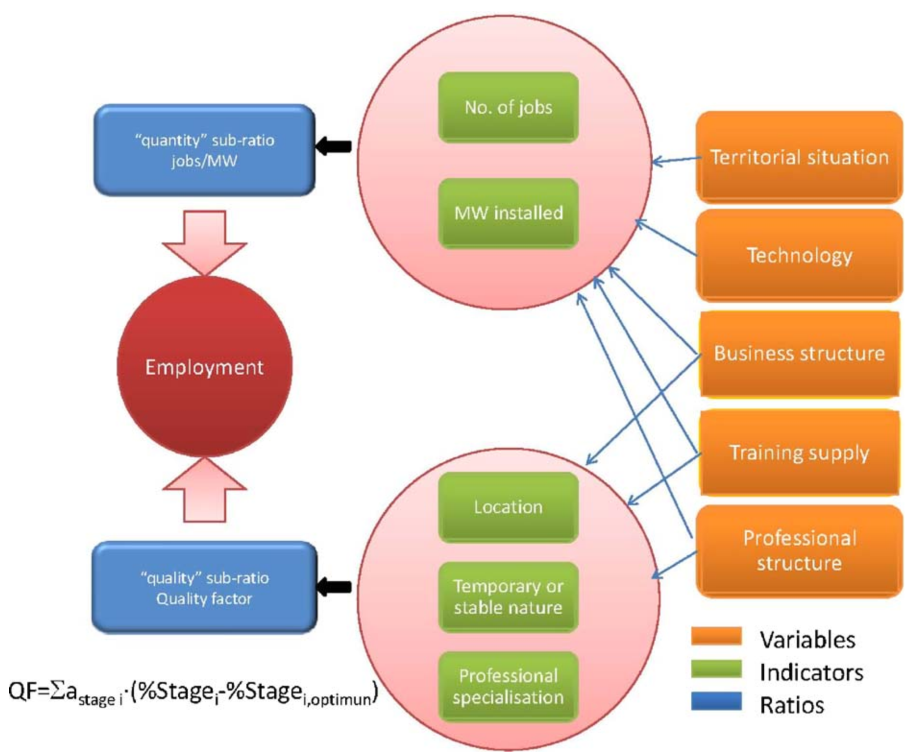

Fig. 2. Conceptual situation of the indicators analysed.

the relative indicators and the terms and scope of the global results.

The main variables that affect employment that were considered indispensable for any study of this type were the following:

(V1) *Territorial situation*: including renewable energy potential, general, energy and electric infrastructure, energy demand;
(V2) *Technology*: activities and stages, degree of maturity of the technology, standards in the sector;
(V3) *Business structure*: presence of SMEs, distribution in the territory, type of activity (usually derivative of other activities);
(V4) *Education supply*;
(V5) *Professional structure*.

Meanwhile, the selected indicators were: volume of employment created, installed power, location, temporary nature, professional specialisation and impact on other sectors related to the variables according to Fig. 2.

3.4. Data gathering

For the fieldwork to gather the necessary data to study, a sequential method was defined that could be schematically summarised in the following activities (Fig. 3):

Activity (A): Selection of territory to analyse and on which we wished to calculate the ratios and indices of employment.
Activity (B): Compilation of secondary sources for the calculation of the ratios and the introduction of the variables such as studies of the territory on economics and employment in the associated sectors, previous reports about the development of the sector in the territory, legislation, studies and analysis of the formal and non-formal educational situation linked with renewable energy, statistical sources, sources monitoring the current situation in the sector and employment offers. The objective consisted of obtaining and defining the current situation in social, technological, economic and regulatory terms in the territory in the scope of renewable energy.
Activity (C): Design and creation of a *Database of the Industrial Sector* of companies directly and indirectly related to the sector with their principal place of business in the territory. As part of this activity there must be a *classification* of the existing companies in light of the technology for using the sources of renewable energy, i.e., the area on which their main activity is centred, and of the type of activity, according to Table 2.
Activity (D): *Fieldwork* for searching for the target information and data through *surveys* directed at the companies (primary information sources) included in the database.

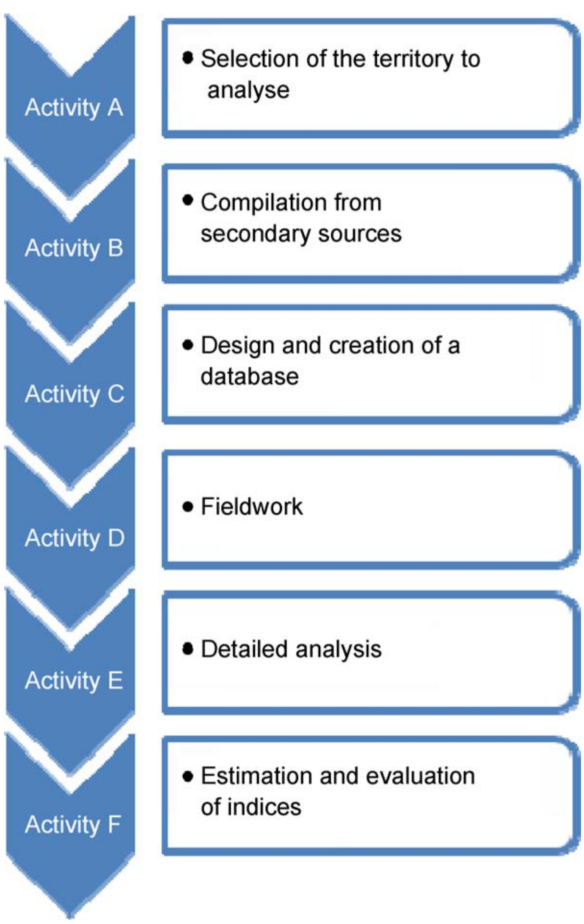

Fig. 3. Sequence of activities proposed.

Table 2
Area and activity of the companies in the renewable energy sector.

Area	Activity
Bioclimatics	Association
Biofuels	Research centre
Wind power	Consultancy
Geothermal	Electricity distribution
Mini hydropower	Equipment manufacture
Hydrogen and fuel cells	Project financing
Agricultural waste	Training
Urban solid waste	Electricity generation
Solar photovoltaics	Import/export of equipment
High temperature thermal solar	Engineering (project development)
Low temperature thermal solar	Installers
Various sources	Equipment maintenance
Other	NGO

The survey had to be designed with the objective of facilitating the segmentation of the socio-economic results such as the turnover of the companies, the size, composition and training of the workforce, the technology used, the main activity, the subsector in which they operate, the specialised staff training needs, etc. to verify the data compiled in Activity (B).

Activity (E): Detailed *analysis* and descriptive statistics of the results of the fieldwork and the creation of a detailed *map* of the *Industrial Sector and Employment* of the installations and companies directly and indirectly related to renewable energy in the territory analysed, and the professionals employed.
Activity (F): Detailed calculation of the ratios and indices selected, applying the different variables, and creation of a global analysis using the empirical results.

4. Pilot case

Once the method had been implemented, to validate it, it was applied to the specific case of the region of Aragon, in the north east of Spain, with a surface area of 47,719 km^2 and the lowest population density in Europe (26.8 hab/km^2 compared to the European average of 70). It was chosen above all for its specific geographic enclave given the territory is full of large energy infrastructure that facilitates the electricity supply generated in the territory and transported to the surrounding regions lacking generation plants and with high demands for electricity.

In particular Aragon has an interesting wind power potential. According to the data of the Spanish Wind Energy Association at the end of 2007 there were 1713 MW installed, which constituted 11.4% of the total wind power installed in Spain [18].

Hydropower use is high (49% of total potential) and there are 56 small hydropower plants with an installed capacity of 254 MW [19].

Table 3
Comparison of the energy structure of Aragon, Spain and the European Union (data for 2007).

	Aragon [20]	Spain [22]	European Union [23]
Primary energy consumption produced with renewables	13.8%	6.9%	7.5%
Electricity production using renewables	36.8%	19.3%	14.9%
Degree of self-supply	29.4%	18.6%	–
Export of electricity generated	60%	1%	–
Percentage of electricity consumed that is of renewable origin	65%	18%	20%
Percentage of electricity consumed that is from wind power	170%	13%	3%

The thermal solar power installed in Aragon in 2007 had a ratio of 4.1 kWth per thousand inhabitants, substantially below the Spanish average (12 kWth/1000 inhabitants) and the European average (21 kWth/1000 inhabitants), with a high development potential of this sector in the region. The photovoltaic power installed in 2007 amounted to 5623 kWp, of which 3619 kWp corresponded to installations connected to the grid and the remaining 2004 kWp to isolated installations [20].

The consumption of solid biomass in 2007 was 174.1 ktoe (the ninth position in the national ranking) while the installed electrical power with biomass was 25.4 MW. During that year the first Aragonese biofuel plant was commissioned with a production capacity of 25,000 tonnes of biodiesel per year.

Although the production of hydrogen is currently residual, there are relevant public and private initiatives at international level for boosting hydrogen as a means for efficiently storing, distributing and consuming electrical energy coming from renewable sources [21].

Table 3 shows the main ratios of its energy structure showing how Aragon is above the Spanish average for establishing renewable energy sources and on track to meet the objectives set by the European Union for the year 2020.[2]

Although energy has always been a basic strategic factor in the development of the autonomous community of Aragon, the abundance of renewable energy resources, the institutional support and the creation of its own technological and business network have been determining factors in the development of renewables in the region [24].

The immediate future in Aragon will continue to offer a leading role to the renewable energy sector as it does not emit greenhouse gases and improves the reliability of the supply. In addition in a economic context such as today's in which it is even more important to promote other ways of organisation that are in tune with growth and employment, without forgetting the effort to protect the environment, renewable energy will see its position reinforced as the most suitable source for small and medium-sized enterprises [25].

4.1. Selection of the territory to analyse

To validate the method implemented, a specific study was carried out in 2008 (using data from 2007) on the pilot case selected. As a prior stage the structure of the renewable energy sector in Aragon was analysed with the compilation of the statistical data available to calculate the ratios and introduce the variables.

4.2. Design and creation of a database

Given that the business activities surrounding the exploitation of renewable energy are numerous and cover all the links of the value chain of the energy business, a *Database of the Business Sector* was created with the companies directly and indirectly related to the sector with their principal place of business in the territory. First a rough database was created using professional contacts of the authors, directories of business associations, energy agencies and chambers of commerce, among others, which was refined by means of telephone calls to verify that the company was active, that the contact details were correct and that the company really belonged to the renewable energy sector or similar. The companies classified themselves in an area and activity from those in Table 2.

As a result of this task, it could be verified that in the year 2007 there were 150 companies with their registered office in Aragon whose main activity was directly linked to renewable energy and approximately a hundred potentially related companies that were not included in this study as it was focused on the direct impact.

4.3. Fieldwork

The study was based on a sample group of the 126 companies with which contact could be established and that were the most important in terms of economic and labour impact, as they covered 98% of the sector's turnover and 97% of employment.

The fieldwork was one of the main actions of this study. Specific information was basically sought by means of a survey aimed at the management figure of the companies included in the database.

The *survey* was structured in three parts.

The first part included questions about the year the company was founded, the turnover and the size of the workforce where they had to choose an option from those offered to facilitate the analysis of the results. The second part of the survey included questions about the type and the extent of the employment and the composition of the workforce according to different functional levels (management, production, sales, administration, design, consultancy, and installation and maintenance). The third part comprised open questions on the staffing needs of the company, its success in covering qualified positions, the specific training needs and their expectations for the future. The data compiled in this part is not analysed in this paper.

The questionnaire was made available to the companies as a form that was accessible on the Internet. It was stored on a server and linked to a database where the responses received were saved automatically. The participation of the companies, motivated by interest in the study, was massive with 119 valid surveys, which was 95% of the responses.

In parallel to the survey, visits in person and semi-structured interviews were held with entities, organisms and companies, concluding this stage with a meeting of experts aimed at validating and expanding the information compiled.

4.4. Detailed analysis

Finally we proceeded to the detailed *analysis* of the results drawing up a detailed *map* of the *Industrial Sector and Employment* of the installations and companies directly related to renewable energy in Aragon and the professionals employed. The main results of the analysis applied to the pilot case are presented below.

[2] The European Union, in its Communication of 23 January 2008 from the Commission to the European Parliament, the Board, the European Economic and Social Committee and the Committee of the COM Regions (2008) 30 final "20 20 for 2020: Europe's Climate Change Opportunity", proposes as one of its objectives to triple the share of renewable energy in primary energy consumption, from the current 7–20% in 2020.

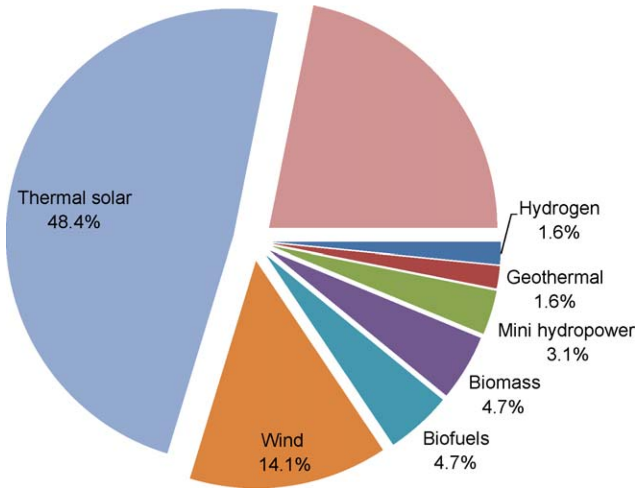

Fig. 4. Distribution of the companies by area of activity.

4.4.1. Business structure in the pilot case

The renewable energy industry in Aragon includes from small companies that carry out their activity in the start-up stages of the business to big companies involved in electricity generation and distribution. This diversity and the flexibility it offers is a guarantee for the renewable energy industry in Aragon. The large, traditional companies provide stability, experience and available capital. The small, more recently founded companies can adapt more easily to change and new technology.

In 1995 Aragon was already competitively positioned in wind and thermal solar energy. Approximately one-third of the companies existing in 2007 had been created before that year although the majority of them had been active in other sectors and were restructured or diversified following the national trend. If we analyse the age of the companies by technological area, the maturity of Aragonese companies in the field of wind energy stood out, a large part of them (78%) had been created before 1995, as did the youth of the companies dedicated to solar photovoltaic energy, where more than half were established after 2000.

Fig. 4 shows the distribution of the Aragonese companies according to their area of activity.

The small percentage of companies devoted to wind energy may be surprising given the high installed capacity of this technology in Aragon. The activity is concentrated in a very small number of specific companies in the sector, that produce wind power technology and/or development, and a larger number of businesses that run the wind farms that were not incorporated into the database as their principal place of business is outside of Aragon.

Fig. 5 shows how the companies with their principal place of business in Aragon in the three stages considered in the wind, thermal solar, solar photovoltaics and general sectors are distributed.

A strong technological base in the wind power sector is observed while in both solar sectors companies devoted to the installation of active solar power systems dominate.

By size, more than half of the Aragonese companies have less than 10 employees, 35% employ 10–50 people and there are no companies with more than 1000 employees (Fig. 6).

The larger companies are concentrated in the wind energy sector dedicated to the manufacture of components. At the same time, it is relevant that the rest of the wind power companies in Aragon are small (less than 50 employees), as a result of their activity, which is basically the operation and maintenance of wind farms.

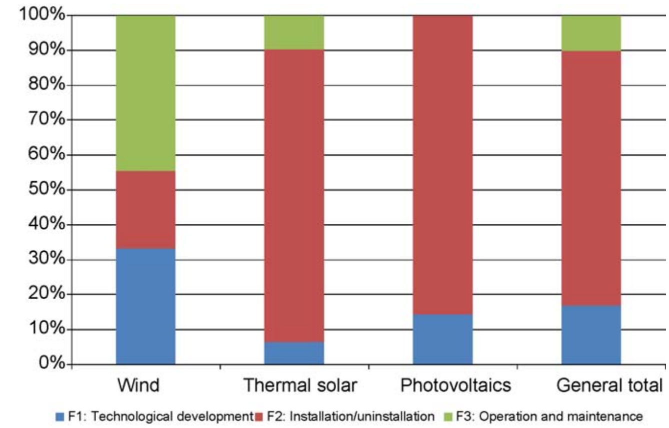

Fig. 5. Distribution of the number of companies by stages of the life cycle of each technology.

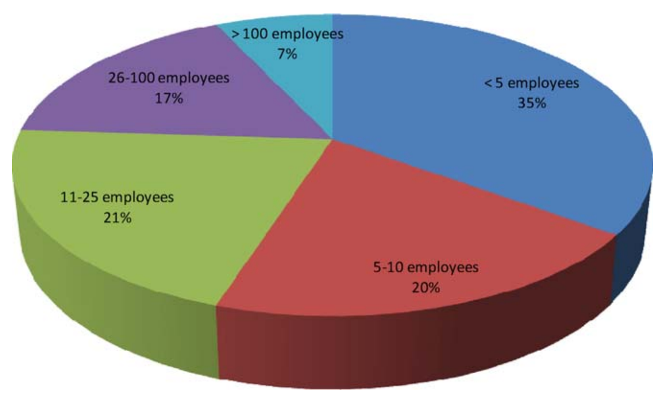

Fig. 6. Size of the companies by number of staff.

It can be concluded that the renewable energy sector in Aragon basically consists of micro-businesses and SMEs that are dedicated to marketing and installing equipment, fundamentally in the solar power sector (solar receivers for solar hot water and, more recently, photovoltaic panels) and SMEs and large companies whose main activity is the manufacture of equipment (photovoltaic panels and thermal solar collectors, wind turbines).

Regarding turnover, 44% of Aragonese companies indicate that their annual turnover was below 500,000 euros and 23% above 3 million euros (Figs. 7–8).

If we group the companies by technology again, from the data in Table 4 we can deduce the significant weight of wind power on the

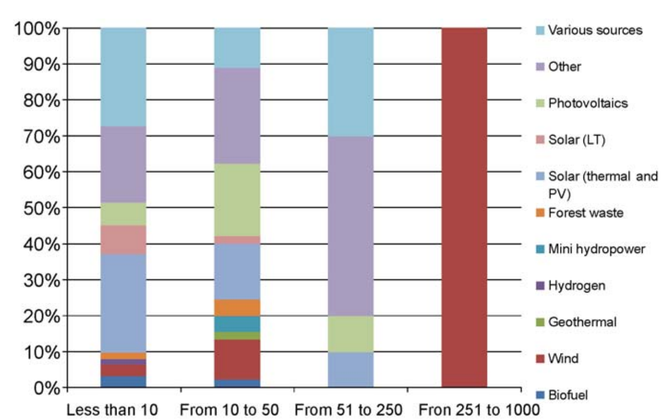

Fig. 7. Presence of the sectors in the different turnover ranges of the companies.

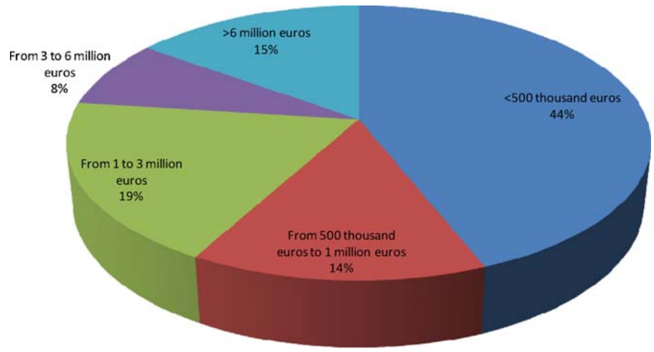

Fig. 8. Size of the companies by turnover in Aragon.

Table 4
Contribution of the sectors to the generation of wealth.

	Wind	Solar (thermal and PV)	Solar thermal (LT)	PV	Biofuel
Less than 1 M€	33.3	79.2	66.7	42.9	66.7
More than 1 M€	66.7	25	33.3	57.1	33.3

wealth generated by the renewable energy sector in Aragon: two-thirds of these companies have an annual turnover of more than 1 million euros (because they are, on one hand, component factories and, on the other, large wind farms). At the opposite end there is the thermal solar sector, with lower levels of turnover as they are mainly companies dedicated to the installation of small systems within the residential and tertiary sectors.

It has been estimated from the kW h produced and the average price of the electricity that the activity of renewable electricity generation makes up little more than 1% of Aragon's GDP while if we add the average turnover of the companies with direct activity in the field of renewable energy (engineering companies counted in the services sector, manufacturers of equipment included in the industry sector, developers in the energy sector, etc.) this percentage increases to 2% of the total GDP equivalent to the average wealth produced in Aragon by the agriculture and livestock sector.

4.4.2. Employment structure in the pilot case

According to data provided by the companies themselves, in 2007 there were 2500 direct and stable jobs in the renewable energy sector in Aragon. Regarding the data of the survey of the working population for the same year these jobs made up 0.43% of the working population and 2.3% of all jobs in the industrial sector in this territory.

Fig. 9 shows how the greatest impact in global employment terms is from the wind power sector.

4.4.3. Interpretation of indicators and calculation of the ratios

The data compiled in the second part of the survey allowed the direct jobs in the renewable energy industry in Aragon to be counted and presented according to different grouping levels. The rest of the data necessary for calculating the ratios was compiled from statistical sources from the autonomous community of Aragon [19,20].

Fig. 10 shows the evolution of the jobs/MW ratio over the last 10 years for all types of renewable electricity production technology. During this period the ratio varies within the range 1.28–5.54 so if this indicator were to be selected to evaluate the global impact of renewables on employment, the results would be very different depending on the year selected.

We can see how, except for a slight rise in the year 2000, the year of the first Plan for the Promotion of Renewable Energy in Spain, the ratio has been dropping exponentially in spite of the progressive growth of installed capacity, stabilising in recent years around a value of 1.43 jobs/MW installed. The variable "Technology" in the fullest sense is presented here as being of considerable influence on the gross generated employment ratios. The policies of support for renewables boost the installation of new renewable MW that generate local jobs in the construction and installation stage and cause peaks in the employment ratios. As the jobs related to this stage come to an end and jobs in the operation and maintenance stage are incorporated into the chain, these same ratios evolve until they are stabilised. At this point it is the business structure of the sector that must have reached the maturity necessary to sustain the percentage of jobs in the temporary stages of the deployment of renewables over time. Otherwise, these jobs will have a greater socio-economic impact on other territories than the one where the installation is located.

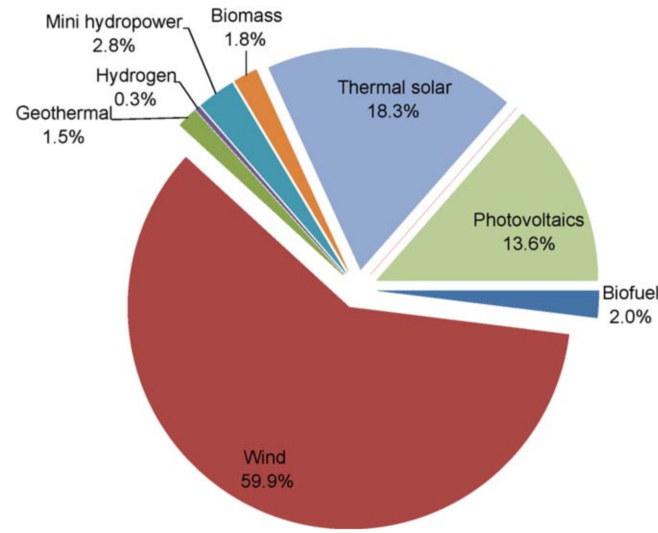

Fig. 9. Distribution of the jobs by area of activity.

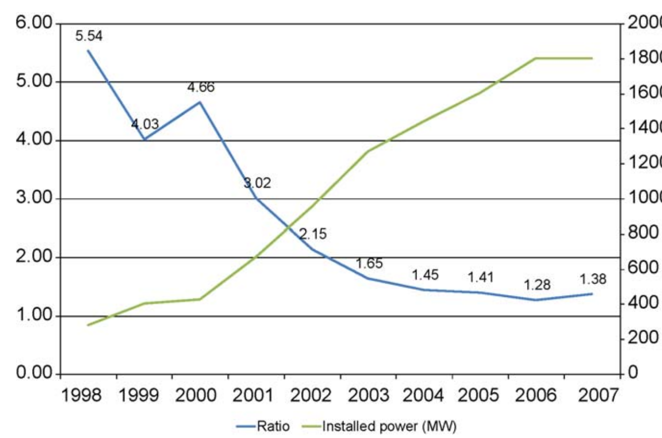

Fig. 10. Evolution of the employment ratios over time.

To be able to report the jobs/MW ratio in each of the three stages proposed, the activities in Table 2 were regrouped as follows:

- Stage 1: Research Centre; Manufacturer of equipment; Training; NGO; Other,
- Stage 2: Association; Consultancy; Project financing; Importing/distribution of equipment; Engineering; Installers; Developer and/or management,

Table 5
Calculation of the jobs/MW ratio and compilation of the same indicator in different studies.

	Installed power	Jobs	Ratio F1	Ratio F2	Ratio F3	Ratio Total	Ranges	Refs.
Wind	1713 MW	1500	0.79	0.02	0.05	0.86	0.68–2.51	[16,26]
Thermal solar	10.4 m^2 (−1.000)	450	1.60	40.41	0.00	43	7.5	[10]
Solar photovoltaics	8700 kWp	350	10.25	28.12	–	38	15–30	[27,28]
Total renewables	1805 MW	2500	0.76	0.52	0.07	1.38	–	–

- Stage 3: Distribution and regeneration of electricity; Maintenance of equipment; Organisation.

Grouping the data compiled in the survey by technological area and based on the data of installed power published [20] the jobs/MW ratios for the year 2007 were estimated for each of the phases of the three majority areas and the total ratio was compared with those obtained in other studies. Table 5 reflects this data.

Firstly the value of the ratios confirms what was expected in terms of the volume of jobs generation in each of the phases.

The total ratio is the average of the partial ratios adjusted according to the employment structure. It can be observed that the jobs/MW ratio for the wind power sector in Aragon is nearer the lower limit of the references consulted, originating from analytical studies that assessed impacts on territories in which wind energy had achieved a considerable degree of maturity in both its business structure and installed power.

Regarding thermal solar energy, an extremely high ratio was noticed in comparison with the reference found. This is a consequence of the companies devoted to thermal solar power at the time of the study being fundamentally dedicated to the installation of systems, which in a seasonal scenario may result in this indicator appearing smaller.

Finally, the ratio obtained for photovoltaic energy is of same order of magnitude in the range of 15–30 direct jobs per MW that can be found in similar studies [27,28] although it is a little beyond the limits. Nevertheless the data of 30 jobs/MW is for Germany, which is the largest world market for photovoltaics, so the creation of jobs in less mature markets, such as the emerging market in the pilot case, can be expected to be greater.

The results obtained in this approach highlight the need know the magnitude of these ratios for a certain situation that is defined by all the variables considered. Therefore, to estimate the employment created with the establishment of renewable energy sources it does not seem adequate to use ratios coming from studies of other territories. Even for the same territory it is advisable to apply them from an in-depth knowledge of the situation given their dynamic character, as reflected in Fig. 10.

Fig. 11 shows the percentage of jobs in each of the three stages and reveals a high percentage in the technological development stages in the wind power industry, key for the development of the sub-sector in Aragon. The deployment of renewable energy sources can only generate economic growth in the territory if it is sustained by a technological development in parallel. This stage creates stable, highly qualified jobs.

Likewise it confirms the high intensity of employment required in stage 2 due to solar technology, thanks to the jobs of installation and maintenance of the systems installed in the tertiary and housing sectors; in many cases the result of the application of standards aimed at boosting the use of renewables in buildings [29].

The percentage of jobs in stage 1 of the photovoltaic sector is substantially greater than in the thermal solar sector whereas jobs in operation and maintenance are non-existent as a result of the state of the installations.

The questioned posed by this point would be to find out if this employment distribution in the three stages is close to that of an industrial structure that would agglutinate the whole the chain of business. The greater this proximity, the higher the degree of development of the territory would be within the scope of renewables and the greater their technological independence with the economic impact this implies. For example the employment distribution in the three stages was compared with the results of the study by Singh and Fehrs [9] for wind power, observing how the percentage of jobs in the technological development stages in Aragon, at 92%, is much greater than the 67% reported in this reference, while the proportion of the jobs in the two remaining stages is maintained. This ratifies the significant development of wind power in Aragon, in terms not only of installed power but also of the economic impact linked to the export of the technology.

Fig. 10 demonstrates that the business and employment structure in Aragon has reached a standstill in recent years, which extrapolates the business and employment structure as the optimum situation for all the technology for territorial circumstances considered.

The Quality Factor (QF) ratio was calculated using the deviation from the of the real situation with respect to the optimum with some adjustment factors consistent with the socio-economic impact of the different stages related to the territoriality, the temporary or stable nature and the professional specialisation of the employment.

$$QF = \sum a_{\text{stage}\,i}\,(\%\text{stage}_i - \%\text{stage}_{i,\text{optimum}})$$

The QF values calculated in this way vary between −1 and 1. Table 6 summarises the quality factors obtained.

According to the approach presented, employment in the technological sector of wind power is high quality while in the solar areas it deviates from the predetermined optimum, even more so in the case of thermal solar.

The design of the survey enabled the jobs to be distributed among the different professional activities involved. Fig. 12 shows how the jobs were distributed in the areas of wind, thermal solar and solar photovoltaics and incorporates for reference the average value for the whole sector.

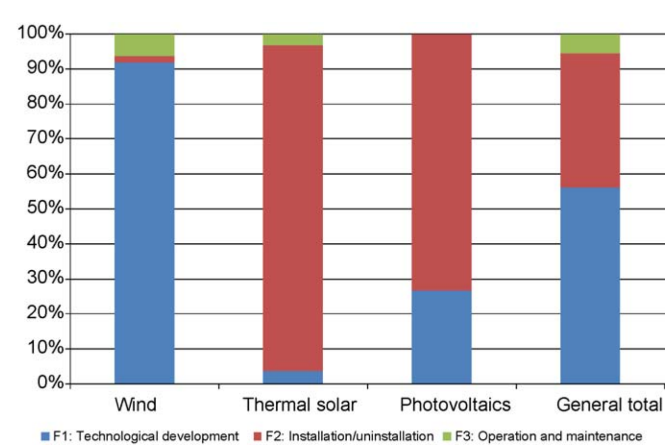

Fig. 11. Distribution of the jobs by area of activity and stage.

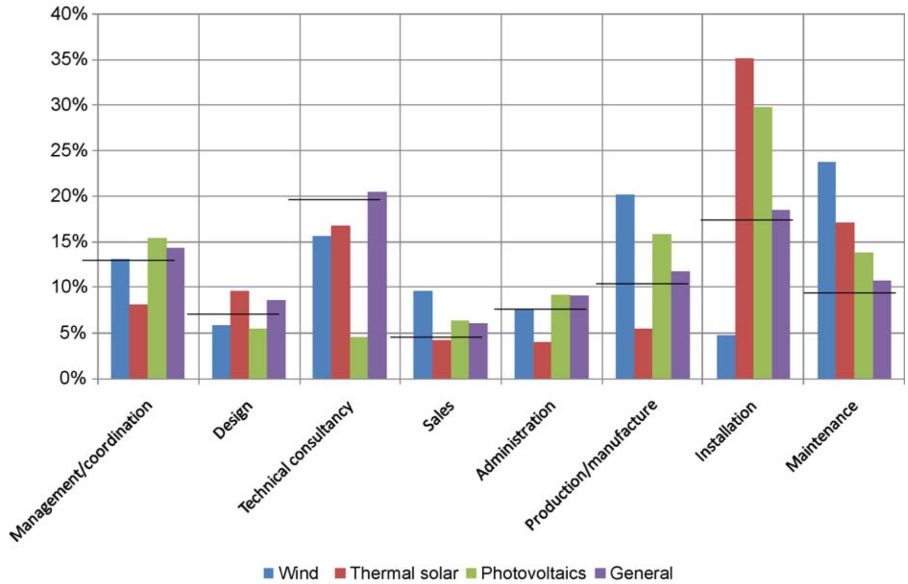

Fig. 12. Distribution of the jobs by area of activity and stage.

Table 6
Indices of the territoriality and temporary or stable nature of the jobs created.

	QF
Wind	0.61
Thermal solar	−0.90
Solar photovoltaics	−0.54

The high percentages of installers in thermal solar and solar photovoltaics stand out, with a slightly higher presence of maintenance staff in the first. In these figure we can also see the presence of Aragonese professionals in activities of component manufacture in the wind and photovoltaic power sectors.

As in all the sectors of activity with high indices of innovation, the training of human capital is a key instrument for the development of renewable energy. Similarly, training becomes an additional asset for companies, improving their competitiveness and favouring the generation of new investment opportunities and business.

Likewise, the data summarised in the previous graph can be presented grouped according to the specific knowledge on the renewable technology they need to have. They have been classified according to three levels of specialisation. The group of professionals with a high level of specialisation includes designers, technical consultants and installers and maintenance staff. This second group is made up of professionals that still need a basic education in this sector and must also have other skills in management or sales. Finally, administration staff and operators do not require specific training.

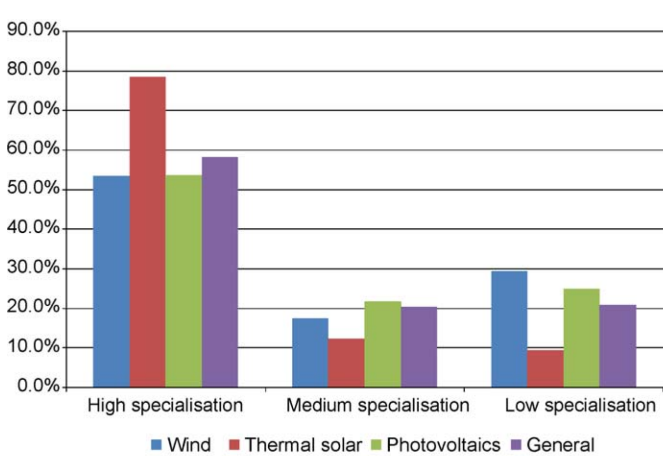

Fig. 13. Distribution of professionals by level of specialisation.

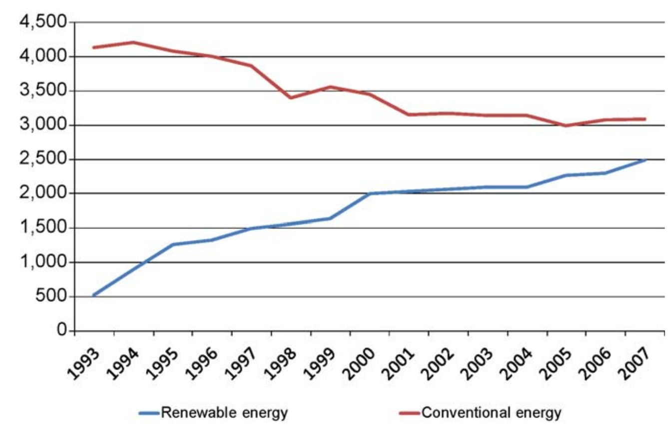

Fig. 14. Evolution of employment in the conventional energy sector and in the renewable energy industry sector.

As you can see in Fig. 13, more than half of the professionals that work in the renewable energy sector in Aragon require high levels of training.

There are studies that warn of the probable reduction of jobs in the conventional energy sector as a consequence of the displacement caused by renewables; the greater the presence of local fossil fuels in the energy structure of the territory, the greater this will be [30]. Given the importance of coal in Aragon,[3] it seems significant to analyse the evolution of employment in the energy sector.

Fig. 14 represents the evolution of the number of jobs in the conventional energy sector according to data of the Industrial Companies Survey of the Spanish National Statistics Institute [31]

[3] Coal is, in addition to renewable energy, a resource indigenous to the territory studied. Twenty-five percent of electricity generation depends on this fuel where 30% is of local origin. Coal mining and its use in thermoelectric plants are almost the only activity in many of its villages.

and in the renewable energy sector, using the information compiled in the surveys, for the last 15 years.

We can see how there has been a stagnation in employment in the conventional energy sector with a tendency inversely proportional to the growth of employment in the renewable energy sector. For the latter the speed of direct job creation has been approximately 130 jobs/year, in the period of the last 15 years, with evident accelerations that coincide with the energy plans of the administration: the first Energy Plan of Aragon (published in 1994), the Plan for the Promotion of Renewable Energy in Spain (2000–2010) and the latest Energy Plan of Aragon (2005–2012).

Nevertheless, when the evolution of the electricity mix is analysed, it can be concluded that the slowing down of employment creation in generation using fossil fuels is not due to the establishment of the renewable energy but to other factors such as the closure of certain thermoelectric plants and the increases in electric power with less employment intensive technology such as cogeneration or combined cycles.

From the number of jobs in the conventional and renewable energy sectors and the electrical power installed over the last 15 years, one can reach the conclusion that, for the energy structure of Aragon, renewable energy generates between 4 and 1.8 times more jobs per MW installed than conventional sources.

5. Conclusions

In the integrated method developed and presented in this paper, specific questions are approached that are not considered in other studies inherent in the impact of the exploitation of renewable energy on the regional economic activity, analysing factors such as the territorial situation, the different stages of the deployment of renewable energy sources, the maturity of the technology and of the industrial sector or the employment quality.

The analytical approach incorporated in the method proposed enables the analyst to decide the level of grouping of the data to calculate the various ratios opting for the definition of a ratio framed by two different sub-ratios: the numeric ratio of jobs generated per MW installed and the ratio of quality expressed in the form of a Quality Factor (QF) per MW installed.

A set of indicators were selected adding a number of specific variables that reflect the employment created, the quality of the jobs measured from the percentage of local jobs or the percentage of temporary jobs, the strength of the human capital as a percentage of jobs in the different functional categories and even the possible displacement of jobs in related sectors.

All of this are integrated into an outside-to-in analysis, in which employment is the core and each level has repercussions on those that surround it, considering that the different variables analysed in the outer levels and the indicators transfer the final influence of these on the ratios.

The method was applied to the specific case of the autonomous community of Aragon (Spain), confirming that the primary sources of information are the most suitable for calculating the ratios of impact on employment, and in the evaluating the indicators for analysing the competitiveness of the sector, the quality of the jobs and the territorial development, among others.

The results obtained by means of the direct application of the method implemented highlight the need know accurately the value of the ratios once the indicators and the related variables were defined. To estimate the jobs created by the establishment of technology to exploit renewable energy, it does not seem suitable to use ratios coming from studies applied to other territories. Even for the same territory, their application has to be from an in-depth knowledge of the situation, a detailed selection of the indicators and the related variables given its dynamic character. The integrated method posed proposes a sequential system that can be extrapolated step by step to other territories and regions in terms of the definition of stages, the selection of indicators, the analysis of related variables and calculation procedures for the ratios of the socio-economic impact of renewable energy on a territory and in particular of its direct and indirect effect on the jobs created in the different stages.

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